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Domain structure formation by electron beam irradiation in lithium niobate and lithium tantalate crystals at elevated temperatures

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We experimentally studied the features of the domain formation by focused electron beam (e-beam) irradiation at the room and elevated temperatures in congruent lithium niobate (CLN) [1,2] and lithium tantalate (CLT) crystals covered by an artificial dielectric layer.

The studied samples represented the 0.5-mm-thick *z*-cut CLN and CLT plates. The domain structures have been produced by e-beam irradiation of *z*– polar surface covered by 2.5-μm-thick photoresist layer using scanning electron microscopes Auriga Crossbeam and Merlin (Carl Zeiss). The irradiation parameters and beam positioning were controlled by e-beam lithography system Elphy Multibeam (Raith). The irradiation at the temperatures up to 250 °C was carried out using thermal stage C1003 (Gatan Inc.). The static domain structures were visualized by scanning electron microscopy after selective chemical etching.

The dose and temperature dependencies of the geometrical parameters of the created domain structures were measured. It was shown that the domain area linearly increases with dose. The obtained linear behavior has been attributed to the external screening of the depolarization field by injected charges acting as current in the external circuit during the conventional switching. The domain size increase with temperature was attributed to a significant decrease of the threshold field.

The features of the isolated domain morphology at the room temperature were revealed. A distortion of the domain shape as a result of spontaneous backswitching caused by fast charge relaxation and bulk screening retardation after isolated dot irradiation was found. The effect was not observed for domains created by dot irradiation in arrays due to the additional contribution of the field of injected charges of the whole array to the local switching field. The formation of the domains as a result of linear and stripe irradiation was studied. It was shown that linear and stripe irradiation are similar in the studied width range due to electron scattering in the resist layer. The consideration of the irradiation with various doses as switching by field pulses of various amplitudes and durations allows distinguishing the consequent stages of domain formation. It was shown that the domains grew through the whole crystal wafer and appeared at the opposite polar surface as the quasi-regular chains of isolated domains. The dose increase led to the merging of chains into a continuous stripe domain. The domain shape at the *z*+ polar surface was explained by the effective screening conditions created by the electrode grounded during irradiation.

The revealed qualitative change in the domain morphology with temperature was explained by the highly non-equilibrium switching conditions due to the existence of the artificial dielectric layer and domination of the stochastic nucleation. It was shown that the effect of spontaneous backswitching decreased and then completely disappeared with temperature due to the acceleration of the bulk screening processes. The advantages of the domain formation by electron beam irradiation at elevated temperatures were demonstrated. The obtained results allow creation of the through periodically poled structures with periods from 10 to 40 μm in CLN [2].

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1. E.O. Vlasov, D.S. Chezganov, et al., *Scanning*, **2018**, 7809826 (2018).
2. D.S. Chezganov, E.O. Vlasov, et al., *Appl, Phys. Lett.* (in print).